HEAT TRANSFER

BY

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*SENIOR FACULTY, DEPARTMENT OF MECHANICAL & CIVIL ENGINEERING, **MADE EASY***

*HAVING OVERALL MORE THAN **21** YEARS OF TEACHING EXPERIENCE (**13** YEARS IN **MADE EASY**)*

SYLLABUS

- INTRODUCTION OF HEAT TRANSFER
- FUNDAMENTALS OF THERMAL CONDUCTION
- HEAT TRANSFER THROUGH EXTENEDED SURFACES (FINS)
- TRANSIENT HEAT CONDUCTION (LUMPED HEAT ANALYSIS)

- HEAT EXCHANGERS

- FUNDAMENTALS OF THERMAL RADIATION
- RADIATION HEAT TRANSFER

- FORCED CONVECTION (EXTERNAL FLOW)
- FORCED CONVECTION (INTERNAL FLOW)
- NATURAL (FREE) CONVECTION (EXTERNAL FLOW)

HEAT TRANSFER
(INTRODUCTION)

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QUESTION:1

The wall of industrial furnace is constructed from 0.15m thick fireclay brick having a thermal conductivity of 1.7 W/m-K. Measurements made during steady state operation reveal temperatures of 1400K and 1150 K at the inner and outer surfaces respectively. What is the rate of heat loss through the wall that is 0.5 m by 1.2 m on a side.

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QUESTION:2

The hot combustion gases of a furnace are separated from the ambient air and its surroundings, which are at 25^0C, by a brick wall 0.15m thick. The brick has a thermal conductivity of 1.2 W/m-K and a surface emissivity of 0.8. Under steady state conditions an outer surface temperature of 100^0C is measured. Free convection heat transfer to the air adjoining the surface is characterized by a convection coefficient of h=20W/m^2-K. What is the brick inner surface temperature.

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THERMAL CONDUCTION (FUNDAMENTALS)

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QUESTION:3

Consider a large plane wall of thickness L=0.2m, thermal conductivity K=1.2W/m-K and surface area A=15m^2. The two sides of the wall are maintained at the constant temperatures of $T_1=120^0C$ and $T_2=50^0C$ respectively. Determine:

(a) The variation of temperature inside the wall and the value of temperature at x=0.1 m.

(b) the rate of heat conduction through the wall under steady state conditions.

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QUESTION:4

Consider a spherical container of inner radius 8cm and outer radius 10cm and thermal conductivity K=45W/m-K. The inner and outer surface of the container are maintained at constant temperature $T_1=200^0C$ and $T_2=80^0C$ respectively as a result of some chemical reactions occurring inside. Obtain a general relation to get temperature distribution as a function of radius "r" under steady state conditions and determine the rate of heat loss from the spherical container.

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QUESTION:5

A thick walled copper cylinder has an inside radius of 1 cm and outside radius of 2 cm. The inner and outer radius are held at 310^0C and 290^0C respectively. Assume thermal conductivity varies K varies with temperature as $K=371.9[1 - 9.25\times10^{-5}(T-150)]$. Determine the heat transfer per unit length.

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QUESTION:6

A steam boiler surface is made of a layer of fireclay 12.5 cm thick and a layer of red brick 50 cm thick. If the wall temperature inside the boiler furnace is 1100^0C and that on outside wall is 50^0C, determine the amount of heat loss per square meter of the furnace wall. $K_{fireclay}$=0.533W/m-K and $K_{Red\ Brick}$=0.7 W/m-K.

It is desired to reduce the thickness of the red brick layer in this furnace to half by filling in the space between the two layers by a diatomite whose K=(0.113 + 0.00023T) W/m-K. Calculate the thickness of the filling to ensure the identical heat loss for the same outside and inside temperatures.

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QUESTION:7

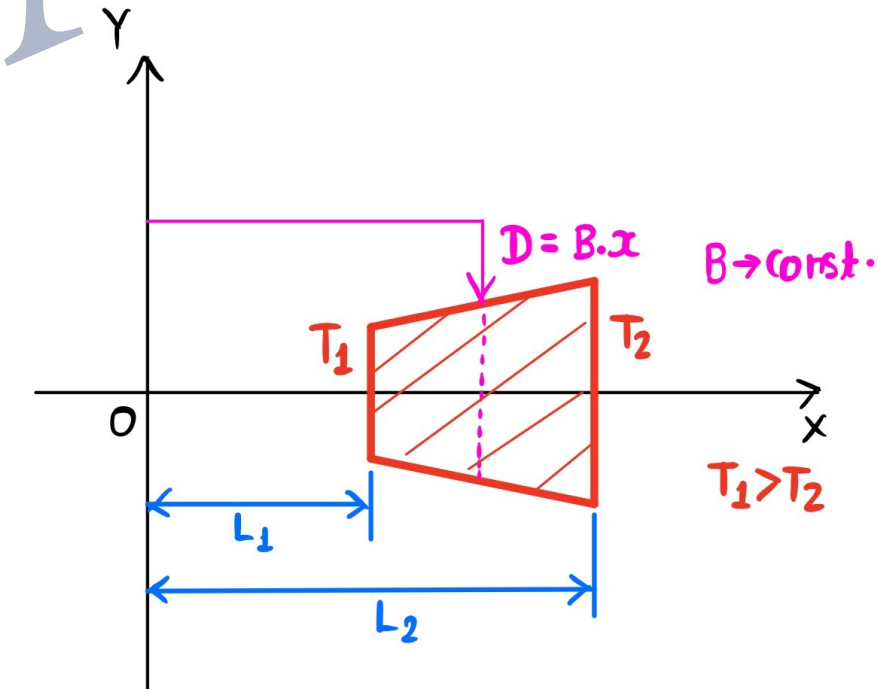
Find:

(i) Rate of Heat Flow

(ii) Temperature distribution as function of x

(iii) Thermal Resistance

For the system shown below.



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QUESTION:8

Consider a base plate of 1200W household iron that has a thickness of L=0.5cm, base area A=300cm^2 and thermal conductivity of K=15W/m-K. The inner surface of the base plate is subjected to a uniform heat flux generated by the resistance heaters inside and outer surface loses heat to the surroundings at T_∞=20^{0}C by convection. Taking outside convective heat transfer coefficient equal to 80 W/m^2-K and disregarding heat loss by radiation, obtain an expression for the variation of temperature in the base plate and evaluate the temperature at the inner and outer surfaces.

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QUESTION:9

Consider a long resistance wire of radius r_1=0.2cm and K_{wire}=15W/m-K in which heat is generated uniformly as a result of resistance heating at a constant rate of $\dot{q}$=50W/cm^3. The wire is embedded in a 0.5 cm thick layer of ceramic whose $K_{ceramic}$=1.2W/m-K . If the outer surface temperature of the ceramic layer is measured to be T_s=45^{0}C, determine the temperature at the Centre of the resistance wire and the interface of the wire and ceramic layer under steady state conditions.

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QUESTION:10

Nichrome having a resistivity of 100 μΩ-cm is to be used as a heating element in a 10 W heater. The Nichrome surface temperature should not exceed 1220^0C. The other design features include:

Surroundings air temperature = 20^0C

Outside heat transfer coefficient = 1.15 kW/m^2-K

$K_{nichrome}$ = 17W/m-K

Find out the diameter of nichrome necessary for a 1 meter long heater. Also find the rate of current flow.

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QUESTION:11

The average heat produced by oranges ripening is estimated to be 300W/m^2. Taking an average size of an orange to be 8 cm and assuming it to be a sphere with thermal conductivity K=0.15 W/m-K, Calculate the temperature at the centre of the orange if its surface temperature is 10^{0}C.

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QUESTION:12

Compute the heat loss per square meter surface area of a 40 cm thick furnace wall having surface temperatures 300^0C and 50^0C if the thermal conductivity of the wall material is given by:

$$K = (0.005\ T - 5\times10^{-6}\ T^2)$$

Where T is in ^0C.

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QUESTION:13

The inside and outside surfaces of hollow sphere $r_i = a$ and $r_o = b$ are maintained at temperatures T_1 and T_2 respectively($T_1 > T_2$). The thermal conductivity varies with temperature as

$$K = K_0 (1+\alpha T+\beta T^2)$$

Derive the expression for total heat flow rate through the sphere.

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HEAT TRANSFER THROUGH EXTENDED SURFACES (FINS)

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QUESTION:14

A turbine blade 6 cm long and having a cross sectional area 4.65 cm^2 and perimeter 12 cm, is made of stainless steel (K=23.3 W/m-K). The temperature at the root is 500^0C. The blade is exposed to the hot gases at 870^0C. The heat transfer coefficient between the blade surfaces and the gases is 442 W/m^2-K. Determine the temperature distribution and the rate of heat flow at the root of the blade. Assume the tip of the blade is insulated.

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QUESTION:15

A cylinder 1 m long and 5 cm in diameter is placed in an atmosphere at 45^0C. It is provided with 10 longitudinal straight fins of a material having thermal conductivity 120 W/m-K. The height of 0.76 mm thick fins is 1.27 cm from the cylinder surface. The heat transfer coefficient between the cylinder surface and atmospheric air is 17 W/m^2-K. Calculate the rate of heat transfer and the temperature at the end of the fins if the surface temperature of the cylinder is 150^0C.

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QUESTION:16

In an experiment to determine the thermal conductivity of a long solid 2.5 cm diameter rod, its base is placed in a furnace with a large portion of its projecting into the room air at 22^0C. After steady state conditions prevail, the temperature at two points, 10 cm apart, are found to be 110^0C and 85^0C respectively. The convective heat transfer coefficient between the rod surface and surrounding air is 28.4 W/m^2-K. Determine the thermal conductivity of the rod material.

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QUESTION:17

A stainless steel pin fin (K=16 W/m-K) 10 cm long and 1 cm in diameter is fitted to a wall which is exposed to a boiling water convection situation where heat transfer coefficient h=5000 W/m^2-K. Check whether fins are desired at this place or not ? Give nice explanation.

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QUESTION:18

An oil filled thermometer well made of a steel tube (K=55.8 W/m-K), 120 mm long and 1.5 mm in thick is installed in a tube through which air is flowing. The temperature of the air stream is measured with the help of thermometer placed in the well. The surface heat transfer coefficient from air to the well is 23.3 W/m^2-K and the temperature recorded by the thermometer is 88^0C. Estimate the measurement error and the percentage error if the temperature at the base of the well is 40^0C.

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QUESTION:19

Compare the efficiency of the plate fin of length 1.5 cm and thickness 2 mm for the following two cases.

(a) Fin material is aluminum (K=210 W/m-K) and the heat transfer coefficient is 285 W/m^2-K.

(b) Fin material is steel (K=40 W/m-K) and the heat transfer coefficient is 510 W/m^2-K.

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TRANSIENT HEAT CONDUCTION (LUMPED SYSTEM ANALYSIS)

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QUESTION:20

A steel tube of length 20 cm with internal and external diameters 10 and 12 cm is quenched from 500^0C to 30^0C in a large reservoir of water at 10^0C. Below 100^0C the heat transfer coefficient is 1.5 kW/m^2-K. Above 100^0C it is less owing to a film of vapour being produced at the surface and an effective mean value b/w 500^0C and 100^0C is 0.5kW/m^2-K. The density of steel is 7800 kg/m^3 and the specific heat is 0.47kJ/kg-K. Neglecting internal thermal resistance of steel tube, determine the quenching time.

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QUESTION:21

Steel ball bearings ($K=50 W/m\text{-}K$, $\alpha=1.3\times10^{-5}\ m^2/s$) having a diameter of 40 mm are heated to a temperature of 650^0C and then quenched in a tank of oil at 55^0C. If the heat transfer coefficient between the ball bearings and the oil is $300 W/m^2\text{-}K$, determine:

(a) the duration of time the bearing must remain in oil to reach a temperature of 200^0C.

(b) the total amount of heat removed from each bearing during this time.

(c) the instantaneous heat transfer from the bearings when they are first immersed in oil and when they reach 200^0C.

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QUESTION:22

The temperature the gas stream is to be measured by thermocouple whose junction can be approximated as a 1mm diameter sphere. The properties of the junction are K=35W/m-^{0}C, ρ=8500 kg/m^3, and c_p=320 J/kg-^{0}C and the convection heat transfer coefficient between the junction and gas is h=210W/m^2-^{0}C. Determine how long it will take for the thermocouple to read 99% of initial temperature difference.

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QUESTION:23

A person is found dead at 5 PM in a room whose temperature is 20^0C. The temperature of the body is measured to be 25^0C when found and the heat transfer coefficient is estimated to be h=8W/m^2-^{0}C. Modeling the body as a 30cm diameter and 1.7m long cylinder, estimate the time of death of that person.

Since 72% of body is full of water, Take the properties of body as the properties of water at the average temperature of body and water i.e. at (37+25)/2 = 31^0C

K=0.617 W/m-K

ρ=996 kg/m^3

c_p=4178 J/kg-^{0}C

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HEAT EXCHANGERS

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QUESTION:24

Steam in a condenser of a power plant is to be condensed at a temperature of 30^0C with cooling water from the nearly lake, which enters the tube of the condenser at 14^0C and leaves at 22^0C. The surface area of the tubes is 45 m^2, and the overall heat transfer coefficient is 2100 W/m^2-^{0}C. Determine the mass flow rate of the steam in the condenser.

The heat of vaporization of water at 30^0C is h_{fg}=2431 kJ/kg and the specific heat of cold water at the average temperature of 18^0C is c_p=4184 J/kg-^{0}C.

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QUESTION:25

A counter flow double pipe heat exchanger is to heat water from 20^0C to 80^0C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160^0C at a mass flow rate of 2 kg/s. The inner tube is thin walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m^2-^{0}C, determine the length of heat exchanger required to achieve the desired heating.

We take specific heats of water and geothermal fluid to be 4.18 and 4.31 kJ/kg-^{0}C.

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QUESTION:26

A two shell pass and 4 tube passes heat exchanger is used to heat glycerin from 20^0C to 50^0C by hot water, which enters the thin walled 2 cm diameter tubes at 80^0C and leaves at 40^0C. The total length of the tube in the heat exchanger is 60 m. The convection heat transfer coefficient is 25 $W/m^2\text{-}^0C$ on the glycerin (shell) side and the 160 $W/m^2\text{-}^0C$ on the water (tube) side. Determine the rate of heat transfer in the heat exchanger

(a) Before any fouling

(b) After fouling with a fouling factor of 0.0006 $m^2\text{-}^0C/W$ occurs on the outer surfaces of the tubes.

TAKE CORRECTION FACTOR F=0.91

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QUESTION:27

A test is conducted to determine overall coefficient in an automotive radiator that is compact cross flow water to air heat exchanger with both fluids (air & water) unmixed. The radiator has 40 tubes of internal diameter 0.5 cm and the length 65 cm in a closely spaced plate finned matrix. Hot water enters the tubes at 90^0C at a rate of 0.6 kg/s and leaves at 65^0C. Air flows across the radiator through the interfin spaces and is heated from 20^0C to 40^0C. Determine the overall heat transfer coefficient U, of this radiator based on the inner surface area of the tubes.

The specific heat of water at the average temperature of water i.e. at $(90+65)/2=77.5^0$C is 4.195 kJ/kg-^{0}C.

TAKE CORRECTION FACTOR
F=0.91

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QUESTION:28

Cold water enters a counter flow heat exchanger at 10^0C at a rate of 8 kg/s, where it is heated by a hot water stream that enters the heat exchanger at 70^0C at a rate of 2 kg/s. Assuming the specific heats of water to remain constant at c_p=4.18 kJ/kg-^{0}C, determine the maximum heat transfer rate and the outlet temperatures of the cold and the hot water streams for this limiting case.

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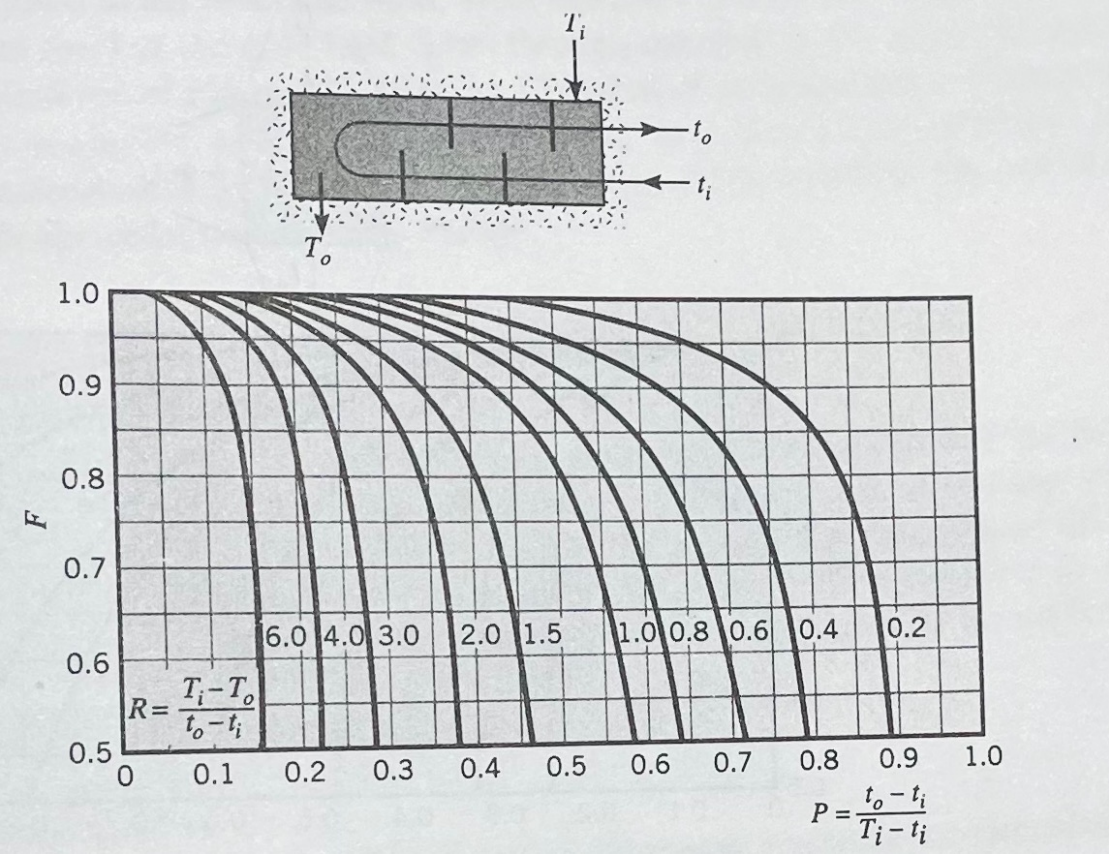
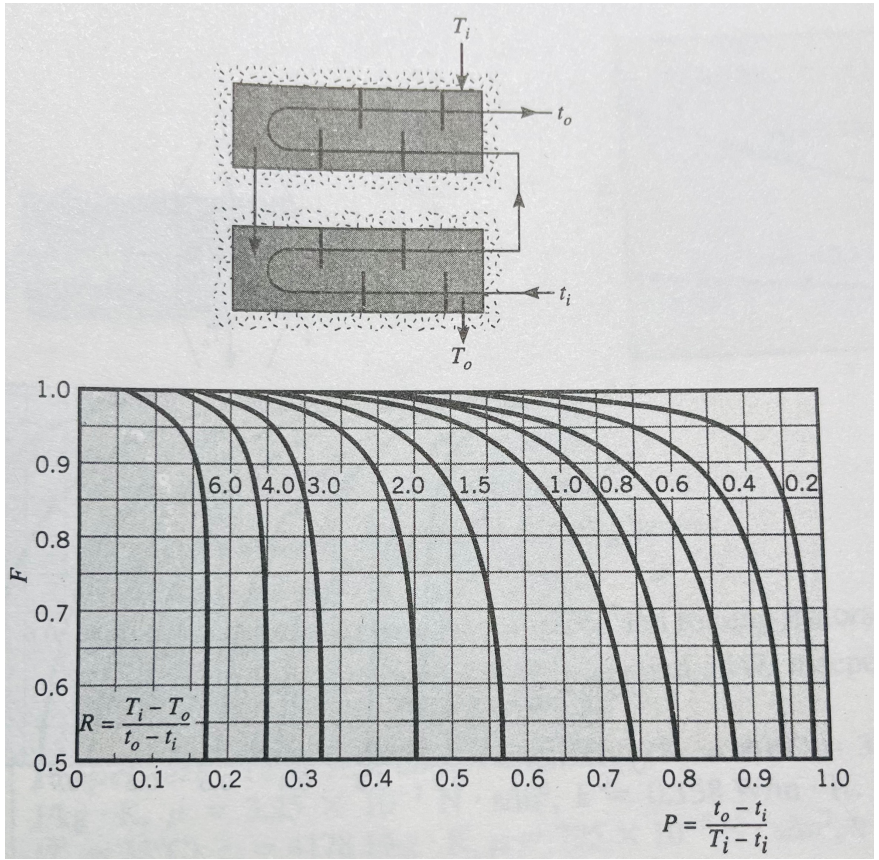
CORRECTION FACTOR FOR SHELL AND TUBE HEAT EXCHANGER



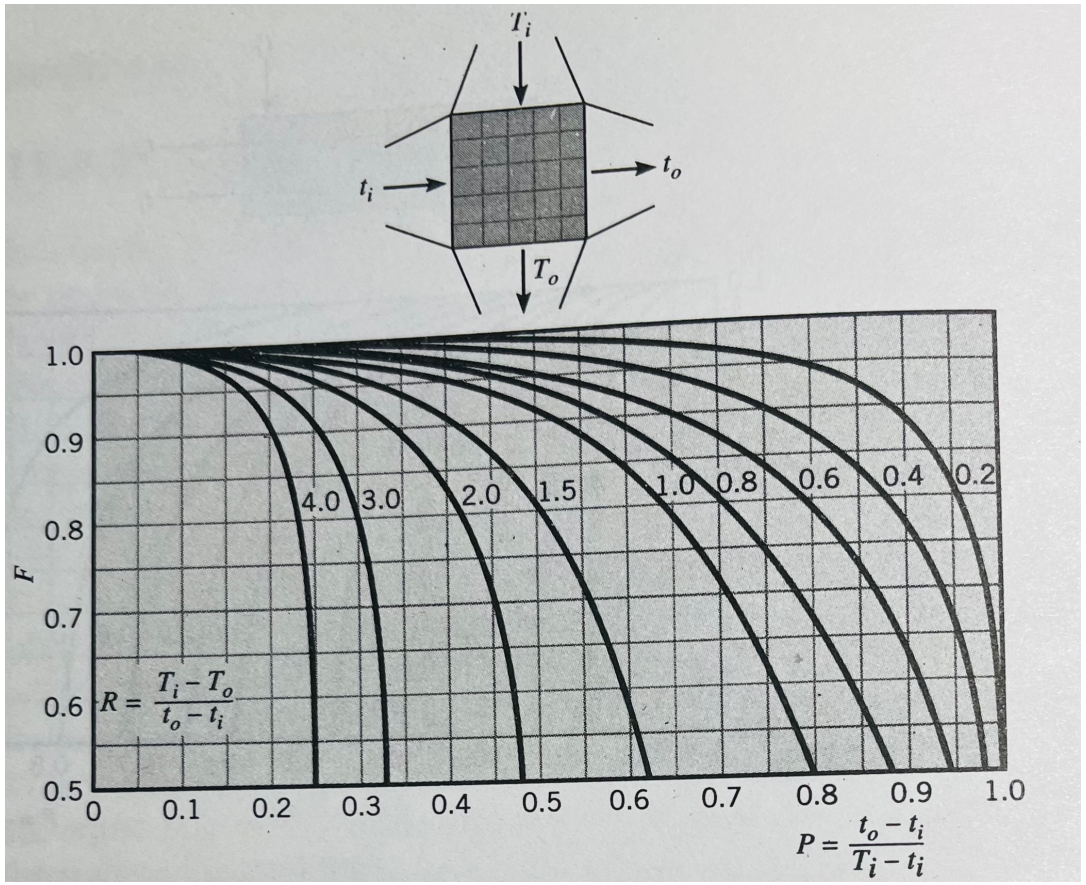
ONE SHELL PASS AND ANY MULTIPLE OF TWO TUBE PASSES

CORRECTION FACTOR FOR SHELL AND TUBE HEAT EXCHANGER



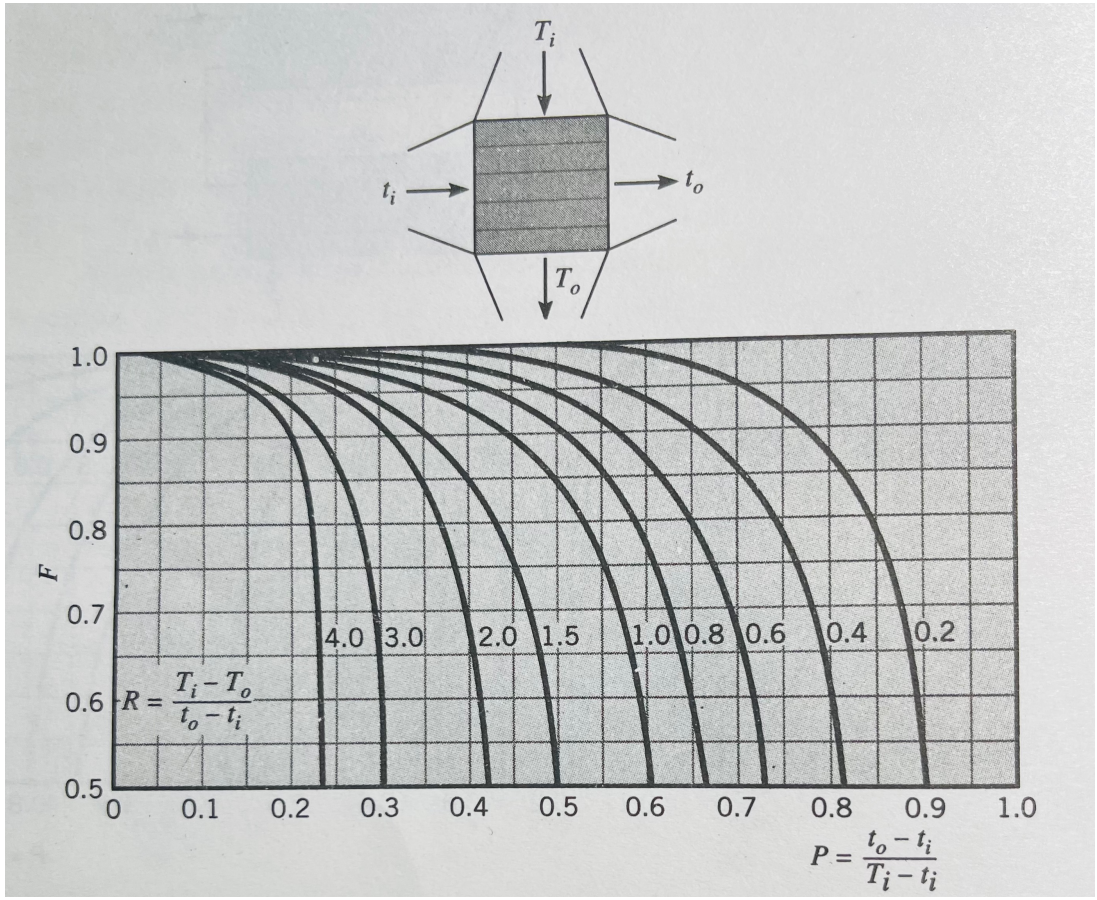
TWO SHELL PASSES AND ANY MULTIPLE OF TWO TUBE PASSES

CORRECTION FACTOR FOR COMPACT HEAT EXCHANGER



SINGLE PASS CROSS FLOW BOTH FLUIDS UNMIXED

CORRECTION FACTOR FOR COMPACT HEAT EXCHANGER



SINGLE PASS CROSS FLOW ONE FLUID UNMIXED AND OTHER FLUID MIXED

THERMAL RADIATION (FUNDAMENTALS)

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QUESTION:29

A small surface area $A_1=10^{-3}$ m^2 is known to emit diffusively and from measurements the total intensity associated with emission in the normal direction is $I_n=7000$ W/m^2-sr. Radiation emitted from the surface is intercepted by the three other surfaces of area $A_2=A_3=A_4=10^{-3}$ m^2,which are 0.5 m from A_1 and are oriented as shown. What is the intensity with emission in each of the three directions. What are the solid angles subtended by three surfaces when viewed from A_1? What is the rate at which radiation emitted by A_1 is intercepted by the three surfaces.

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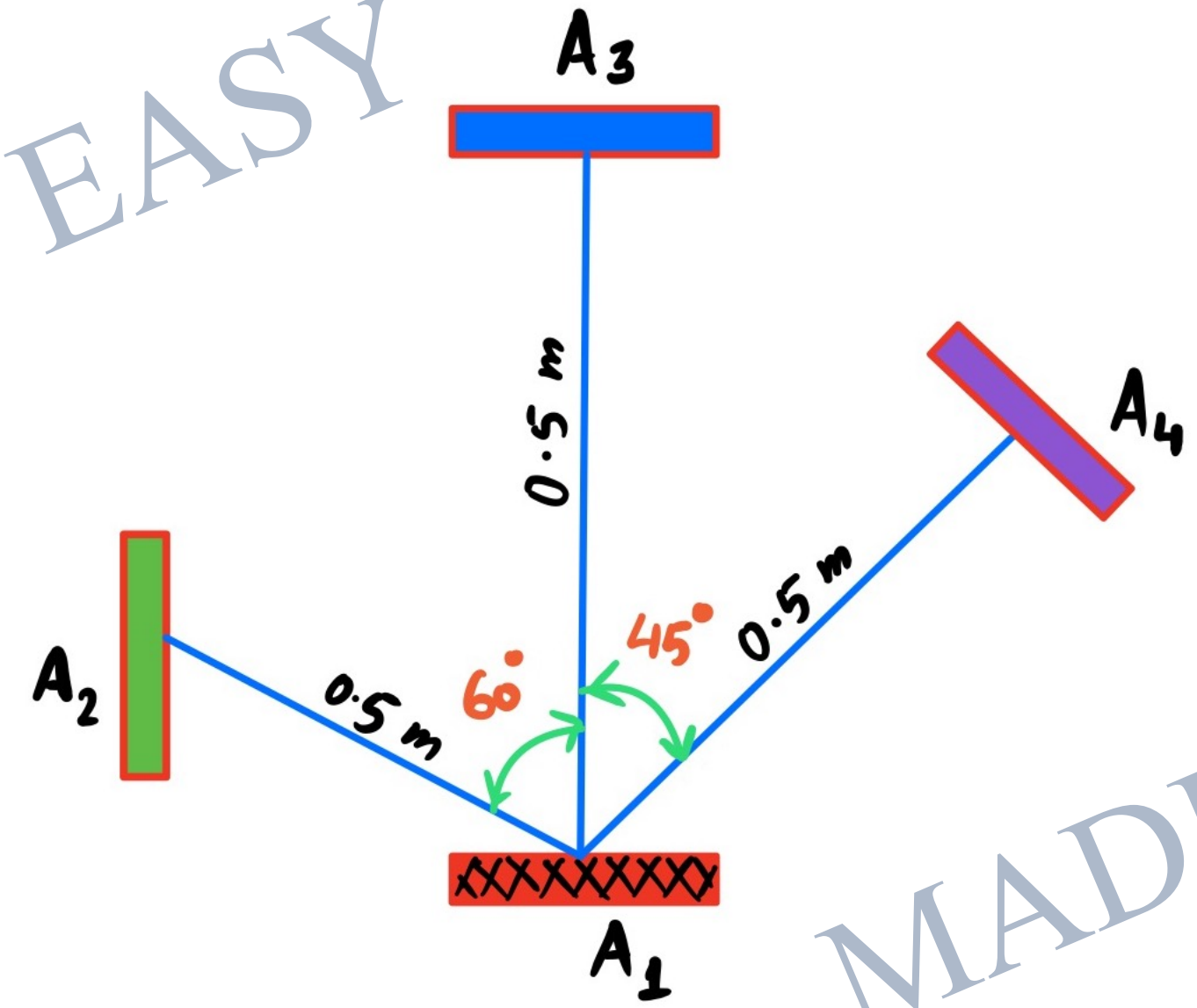

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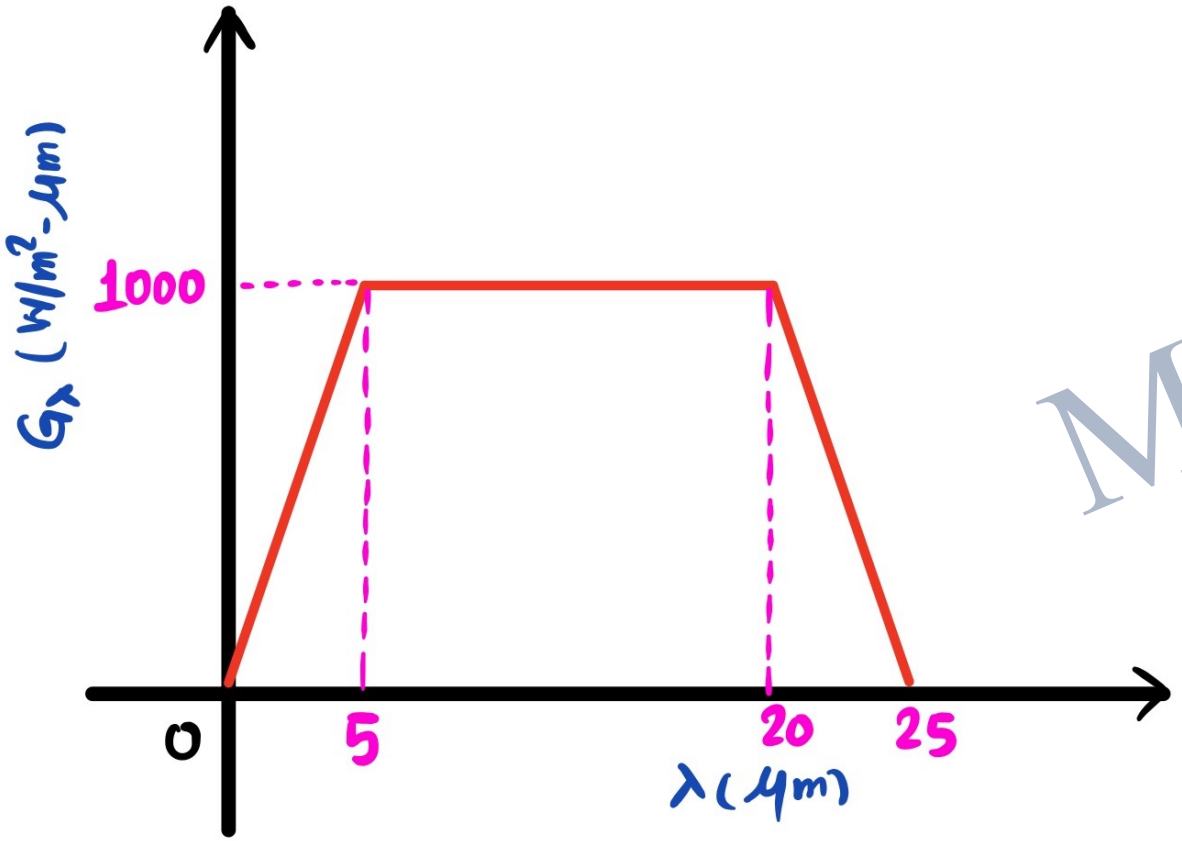
QUESTION:30

The spectral distribution of the surface irradiation is as follows. What is the total irradiation.



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QUESTION:31

Assuming the Sun to be a black body having a surface temperature of 5800K, Calculate:

(a) The total emissive power

(b) The wavelength at which the maximum spectral intensity occurs

(c) The maximum valve of $E_{b\lambda}$

(d) The % of total emitted energy that lies in the visible range of 0.35μm to 0.76μm

(e) The total amount of radiant energy emitted by Sun per unit time if the diameter is assumed to be 1.391×10^{9}m

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QUESTION:32

The spectral emissivity function of an opaque surface is 800K is approximated by the step function and is given below.

$$\epsilon_1 = 0.3 \quad \text{for} \quad 0 \le \lambda \le 3\mu m$$
$$\epsilon_2 = 0.8 \quad \text{for} \quad 3\mu m \le \lambda \le 7\mu m$$
$$\epsilon_3 = 0.1 \quad \text{for} \quad 7\mu m \le \lambda \le \infty$$

Determine the average emissivity of the surface and the emissive power.

(Use Black Body Radiation Function Table.

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QUESTION:33

A diffuse surface at 1600K has the spectral hemispherical emissivity shown as follows. Determine the total hemispherical emissivity and the total emissive power. At what wavelength will the spectral emissive power be maximum??

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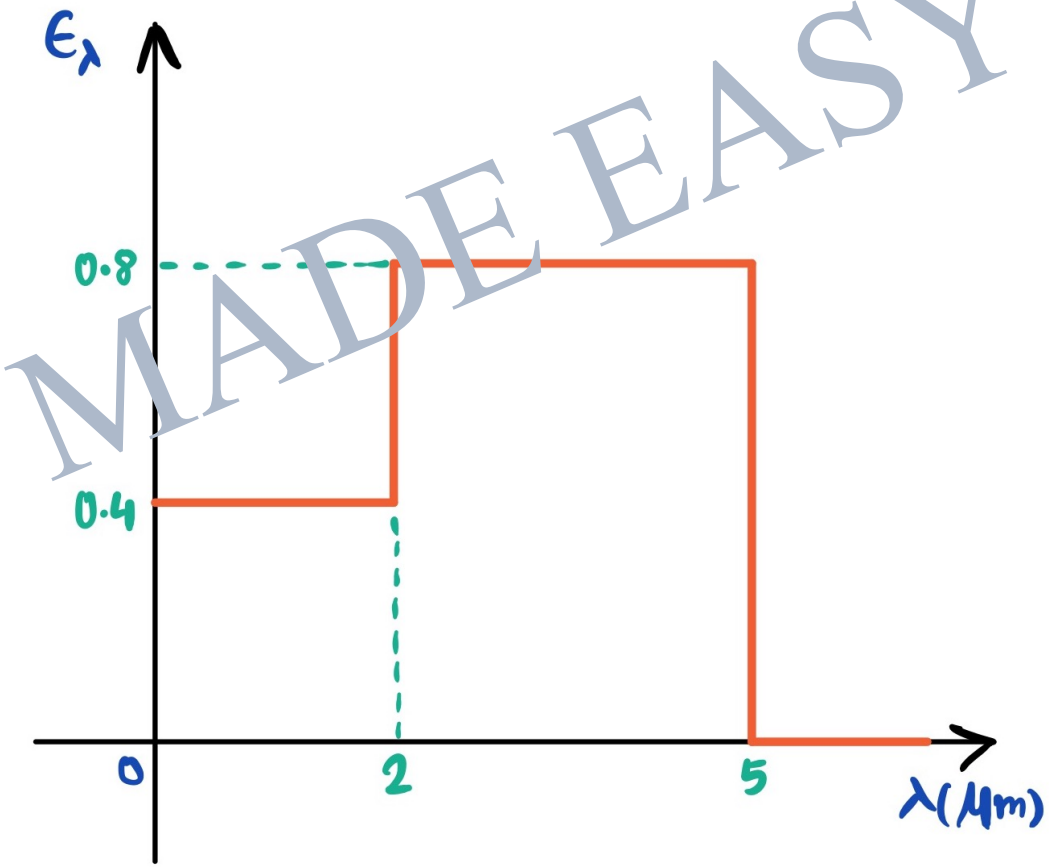

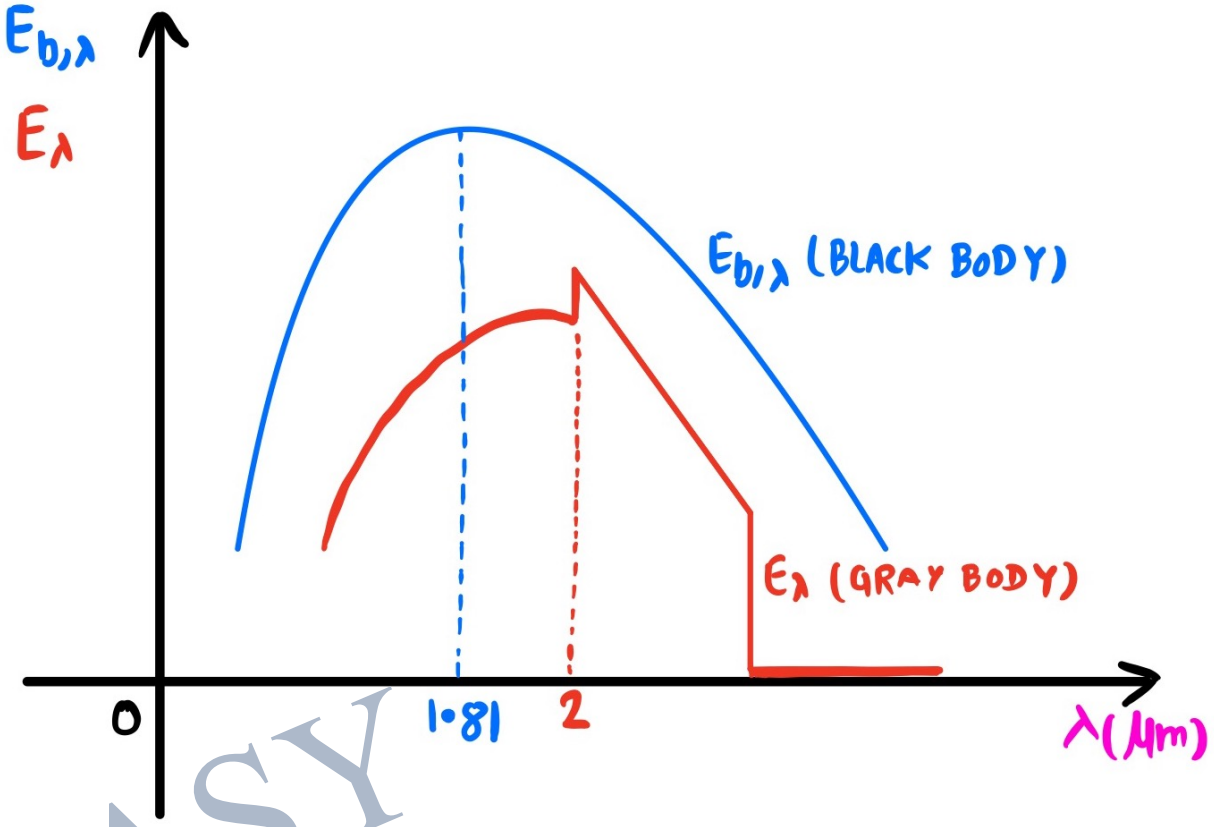

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QUESTION:34

Spectral hemi-spherical absorptivity and the spectral irradiation of an opaque surface is shown as follows:

How does the spectral hemispherical reflectivity vary with wavelength? What is the total hemispherical absorptivity of the surface. If the surface is initially at 500K and has a total hemispherical emissivity of 0.8, how will its temperature change upon exposure to a radiation.

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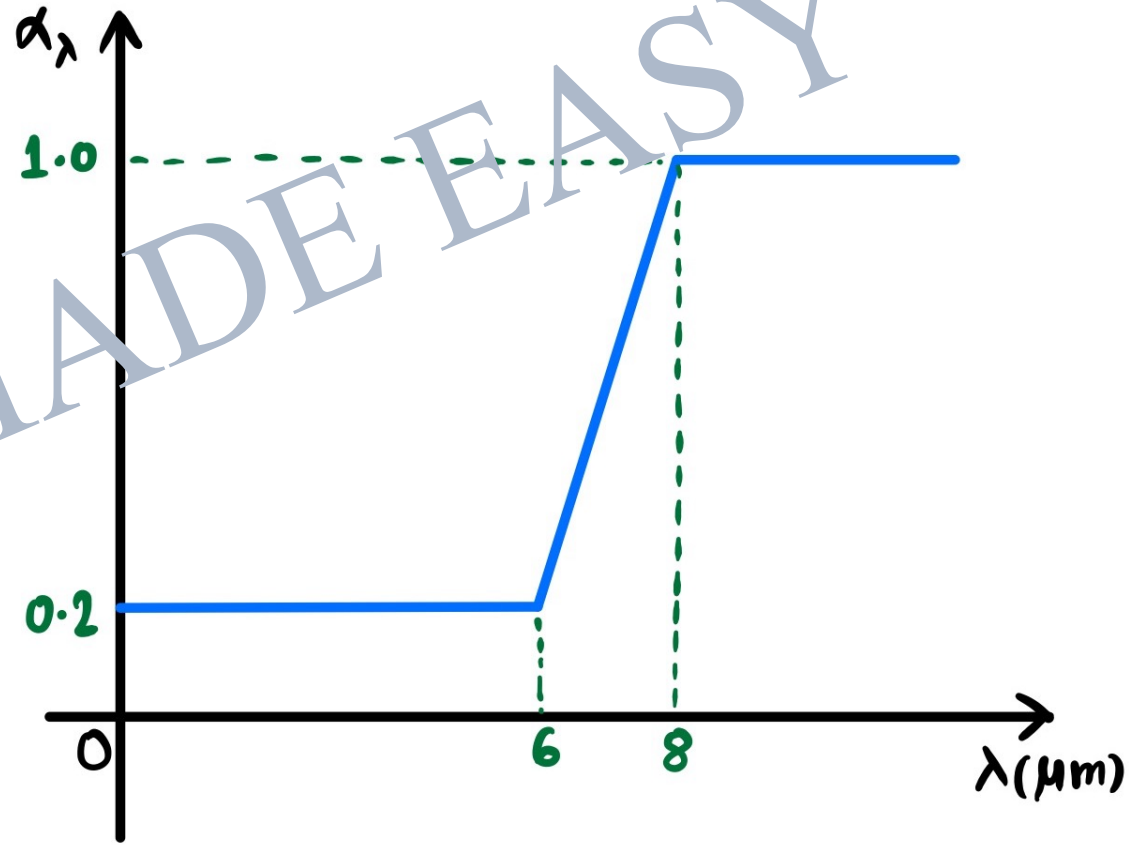

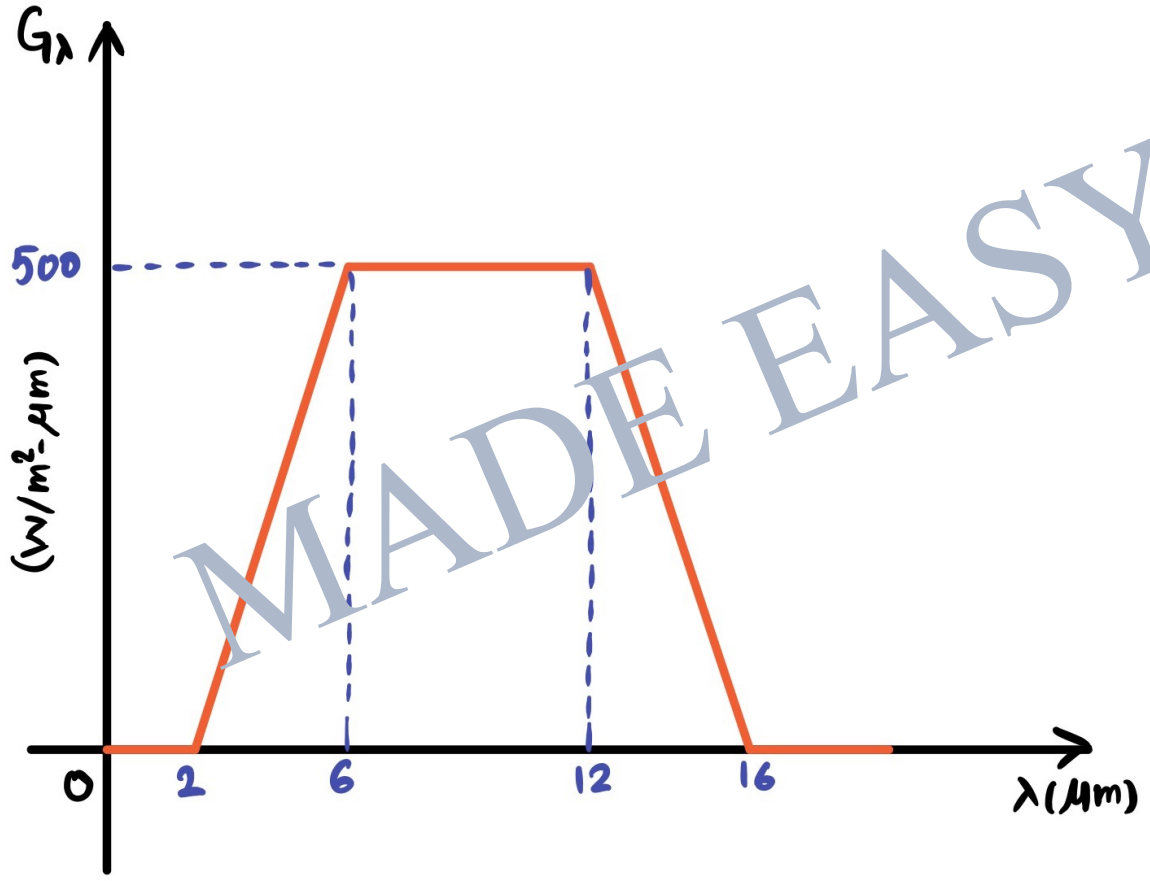

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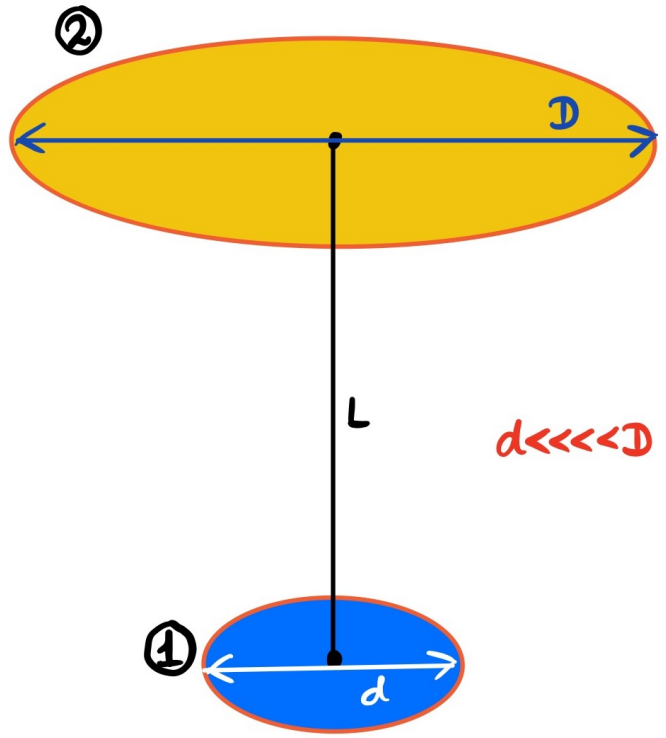
QUESTION:35

Find the shape factor of the configuration as shown in figure (F_{12}) ??



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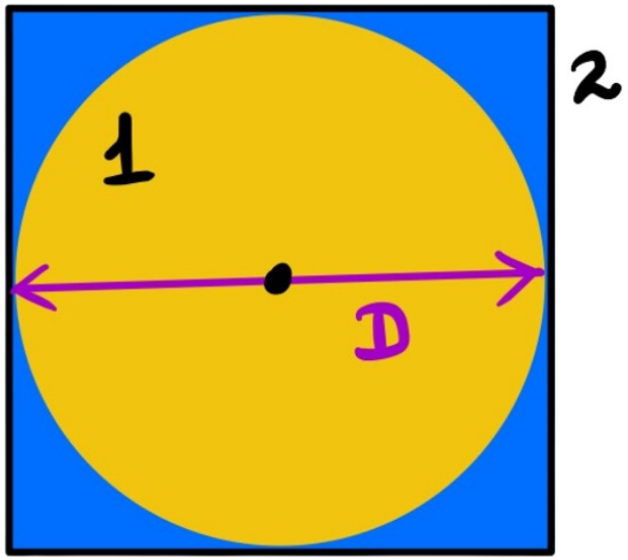
QUESTION:36

Find the view factors F_{21} and F_{12} for the sphere of diameter D inside a cubical box.



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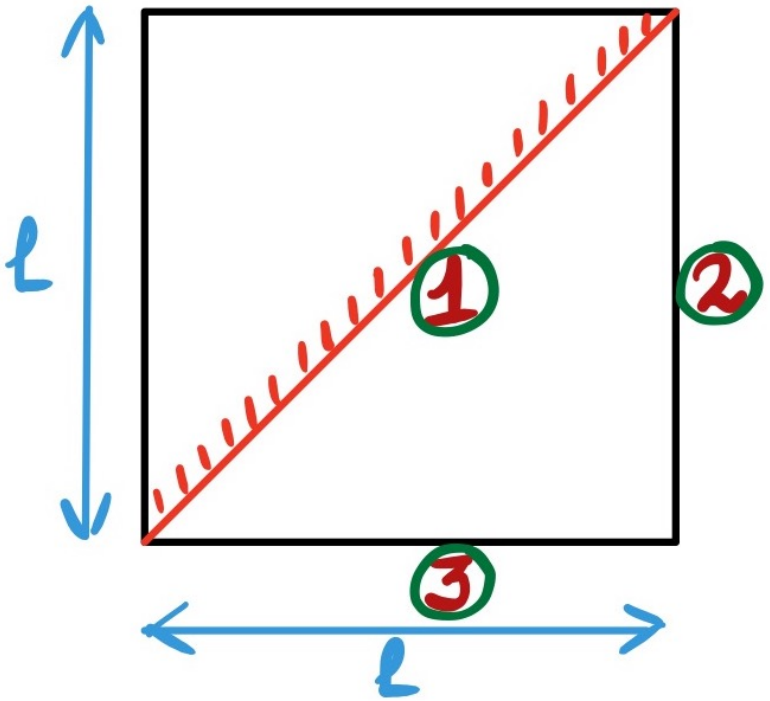
QUESTION:37

Find the view factors F_{21} and F_{12} for the diagonal partition with long duct.



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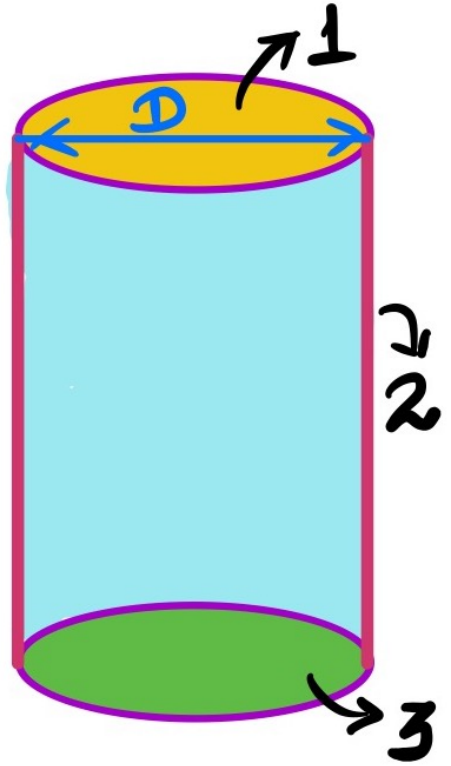
QUESTION:38

Find the view factors F_{21} and F_{12} for the end and side of the circular tube of equal length and diameter.



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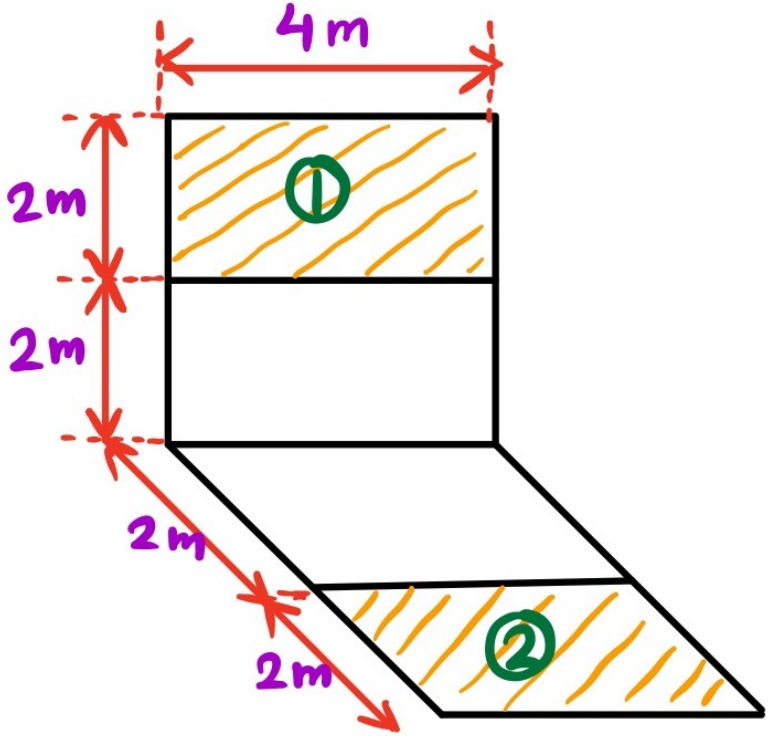
QUESTION:39

Find the shape factor of the configuration as shown in figure (F_{12}) ??



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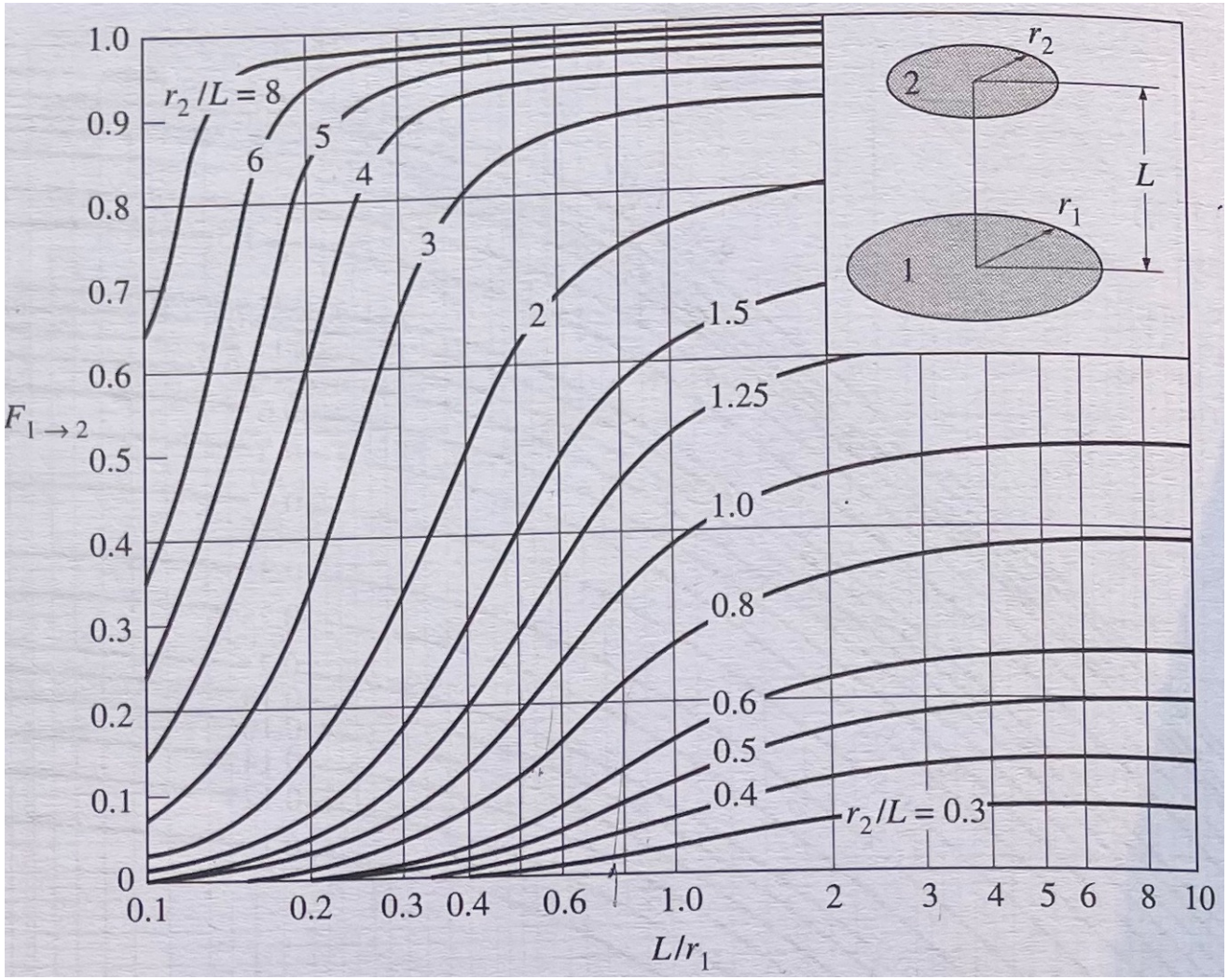

View Factor b/w Two Parallel Discs

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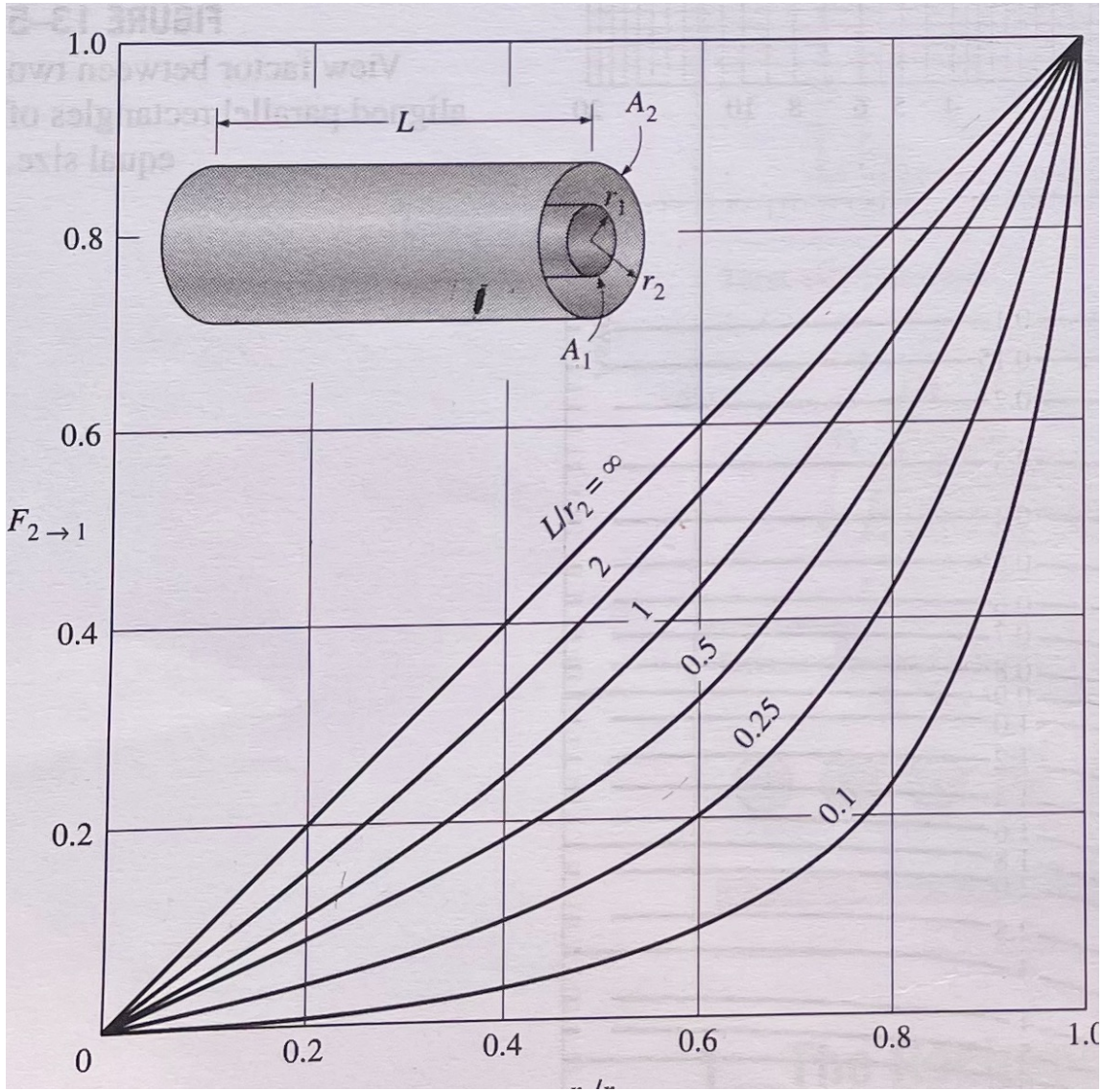
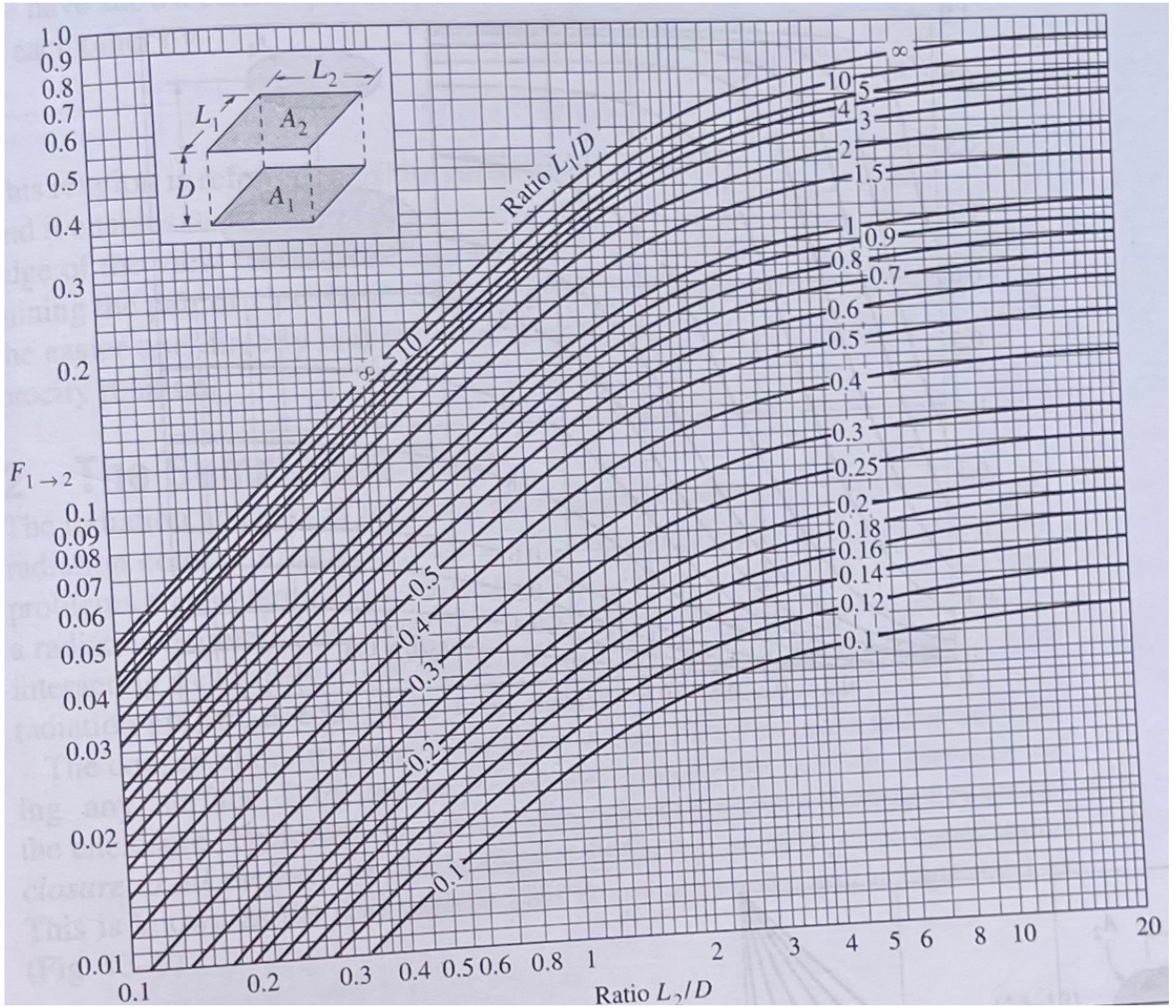


View Factor b/w Two Concentric Cylinders of Finite Length



View Factor b/w Two Parallel Rectangular Plates

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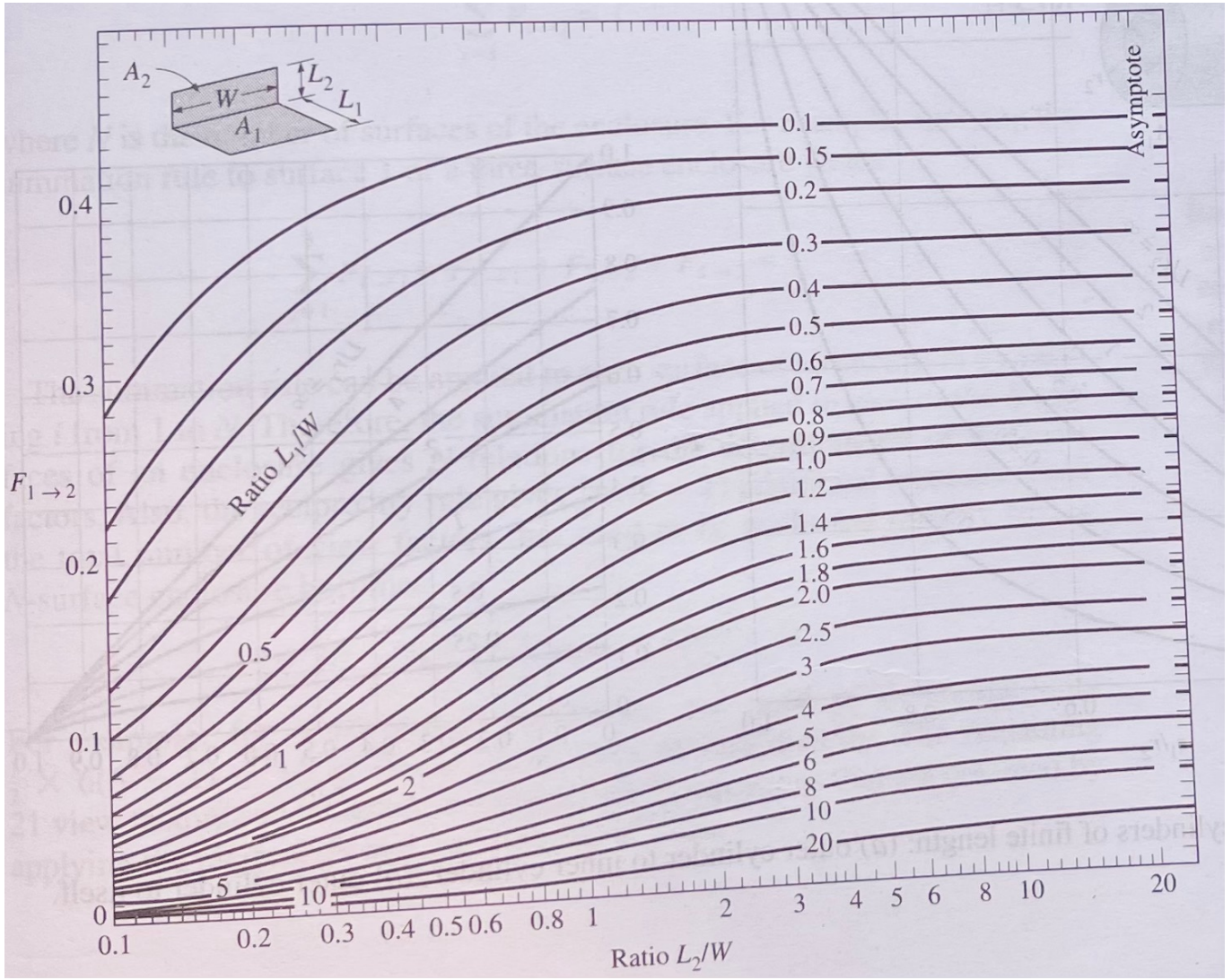

View Factor b/w Two Perpendicular Rectangular Plates with Common Edge

HEAT TRANSFER BY AMIT KAKKAR

RADIATION HEAT TRANSFER

BY

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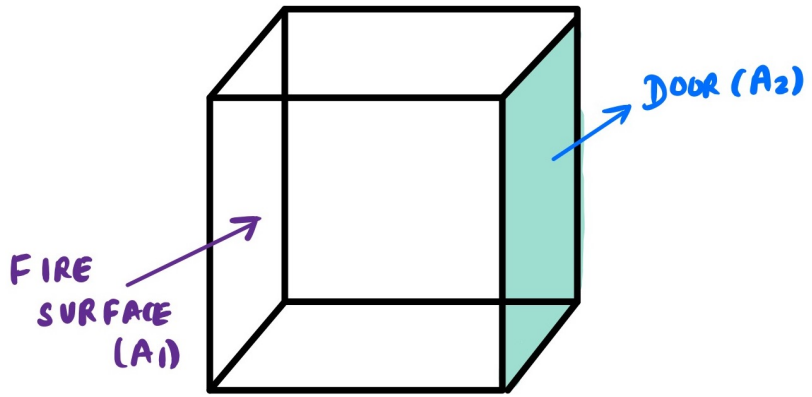
*HAVING OVERALL MORE THAN **21** YEARS OF TEACHING EXPERIENCE (**13** YEARS IN **MADE EASY**)*

QUESTION:40

A cubical oven has one surface which is door. Find the shape factor from the cubical oven to the door. If the side is 0.4 m and five other faces are black and maintained at 600^0C, Find the rate of heat loss if the oven door is kept open.



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QUESTION:41

Two very large parallel plates are maintained at uniform temperatures T_1=800K and T_2=500K and have emissivity's ε_1=0.2 and ε_2=0.7 respectively as shown. Determine the net heat transfer through radiation b/w the two surfaces per unit surface area of the plates.

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QUESTION:42

Consider a cylindrical furnace with $r_o = H = 1$ m as shown in figure. The top (surface 1) and the base (surface 2) of the furnace have emissivity's ε_1=0.8 and ε_2=0.4 respectively, and are maintained at 700 K and 500 K respectively. The side surface closely approximate the black body is maintained at 400 K. Determine the net rate of radiation heat transfer at the surface during steady sate operation and explain how these surfaces can be maintained at the constant temperatures. Take F_{12}=0.38

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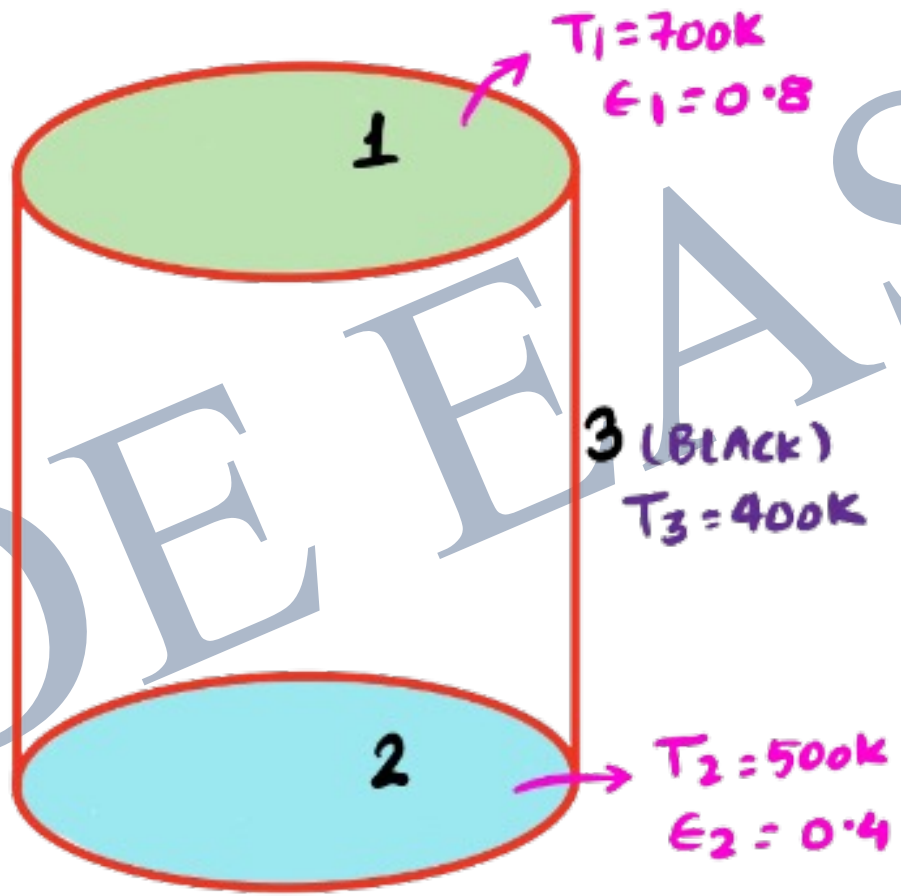

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QUESTION:43

A furnace is shaped like a long equilateral triangular duct as shown in figure. The width of each side is 1 m. The base surface has an emissivity of 0.7 and is maintained at a uniform temperature of 600 K. The heated left side surface closely approximate the black body at 1000 K. The right side surface is well insulated. Determine the rate at which heat must be supplied to the heated side externally per unit length of the duct in order to maintain these operating conditions.

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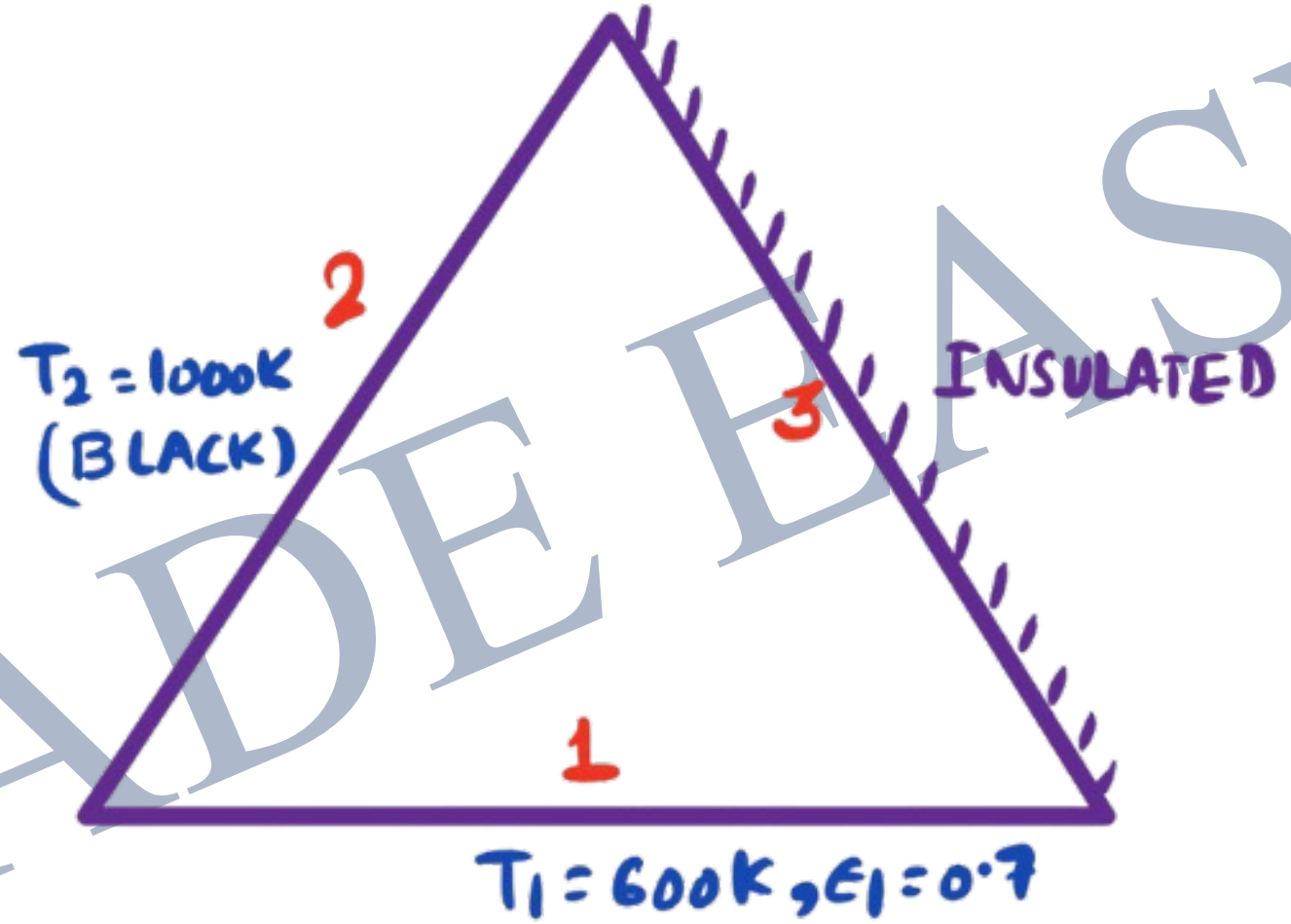

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QUESTION:44

A paint baking oven consist of a long triangular duct in which a heated surface is maintained at 1200 K and another surface is insulated. Painted panels, which are maintained at 500 K, occupy the third surface. The triangular duct is of width W=1 m on a side and the heated and insulated surfaces have an emissivity's of 0.8. The emissivity of the panel is 0.4. During steady state operation, at what rate must energy be supplied to the heated side per unit length of the duct to maintain its temperature at 1200 K. Also find the temperature of the insulated surface.

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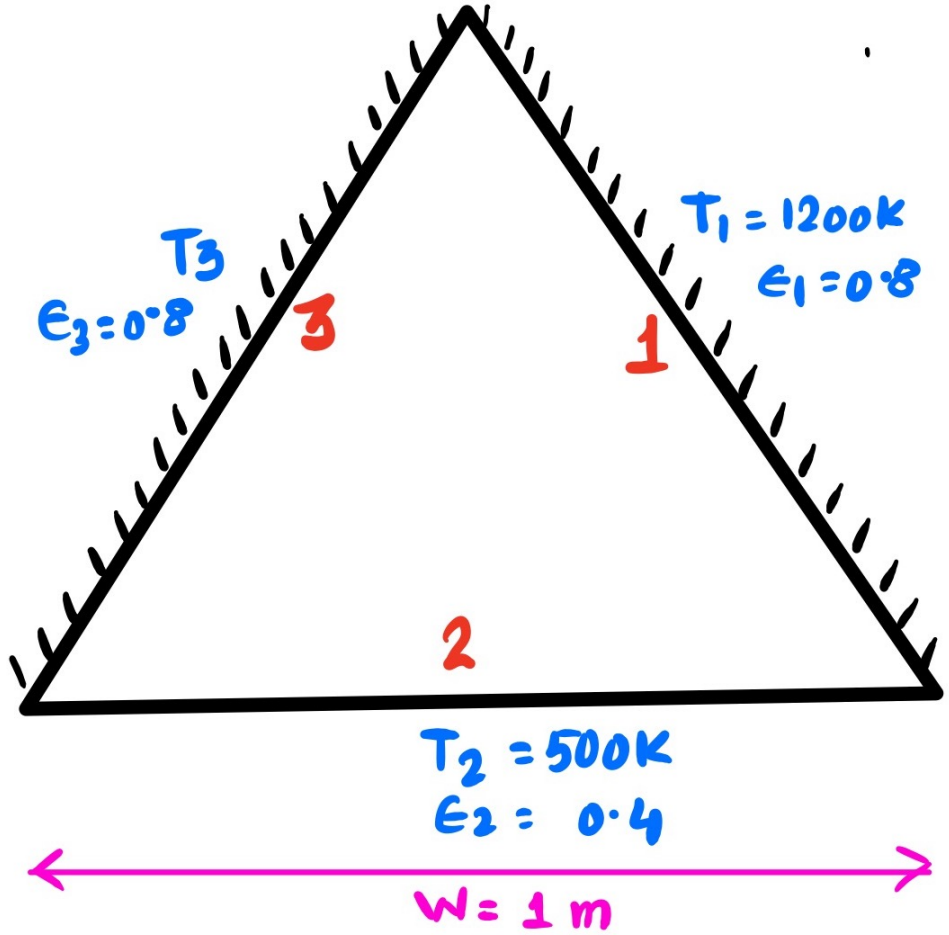

QUESTION:45

A thin aluminum sheet with an $\varepsilon=0.1$ on both the sides is placed between two very large parallel plates maintained at uniform temperatures $T_1=800$ K and $T_2=500$ K and have emissivity's $\varepsilon_1=0.2$ and $\varepsilon_2=0.7$ respectively as shown in figure. Determine the net rate of radiation heat transfer between two plates per unit surface area of the plates. Also compare the results of that without the shield.

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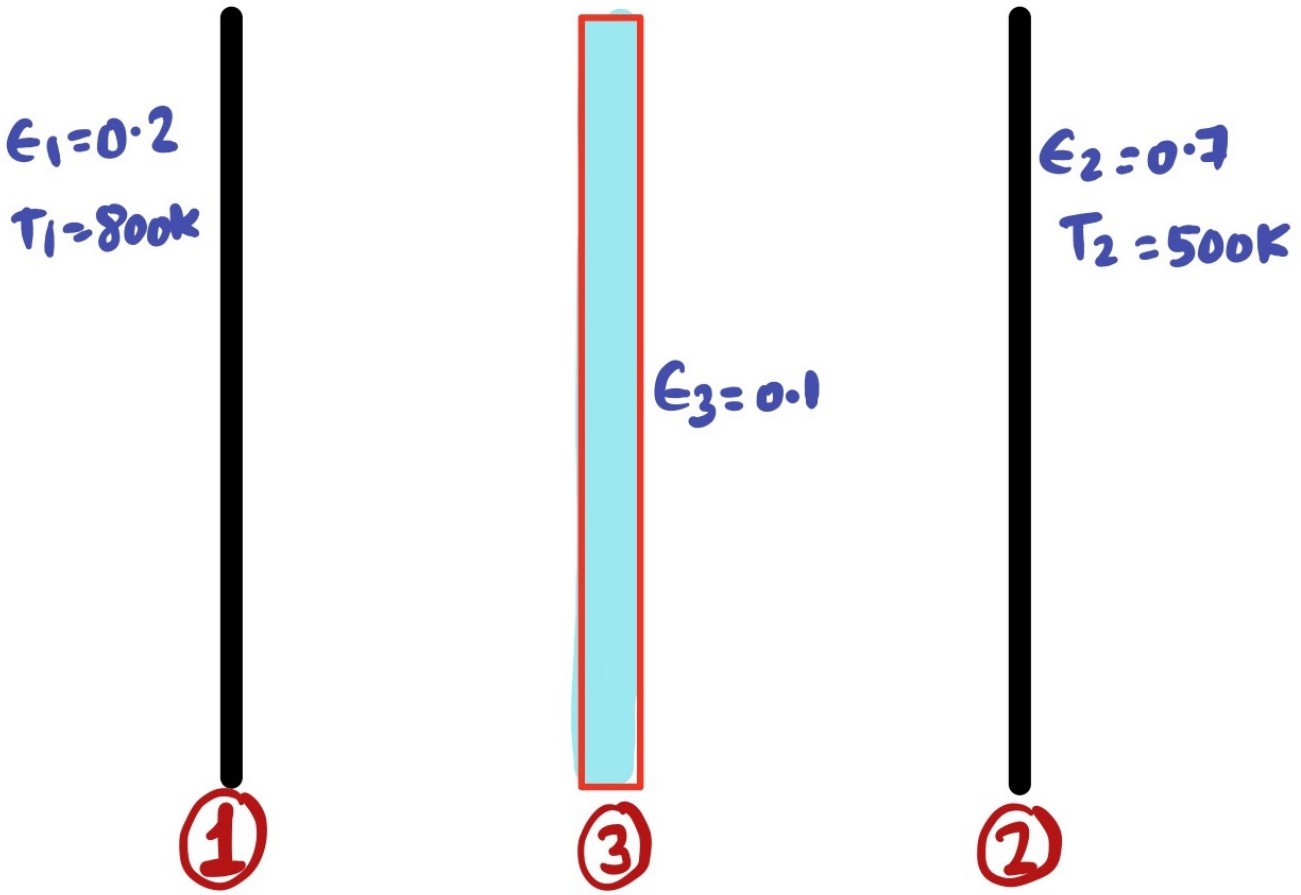

FORCED CONVECTION (EXTERNAL FLOW)

BY

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QUESTION:46

The temperature distribution in the convective heat transfer over a flat plate at a distance y from the plate in transverse direction of flow is given by

$$\frac{T_W - T}{T_W - T_\infty} = \mathbf{a} + \mathbf{b}\left(\frac{y}{L}\right) + \boldsymbol{c}\left(\frac{y}{L}\right)^2$$

Calculate the value of Local heat transfer coefficient and Local Nusselt number on the plate.

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QUESTION:47

Heat is being transferred by convection from water at 48^0C to the glass plate whose surface, that is exposed to the water, is at 40^0C. The thermal conductivity of water is 0.6 W/m-K and that of glass is 1.2 W/m-K. The special gradient of temperature in the water at water-glass interface is $dT/dy = 1\times10^4$ K/m. Find:

(a) The value of temperature in the glass at the water-glass interface.

(b) The heat transfer coefficient.

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QUESTION:48

A fluid (Prandtl number = 1) at 500 K flows over a flat plate of 1.5 meter length, maintained at 300 K. The velocity of the fluid is 10 m/s. Assuming kinematic viscosity $\nu = 30 \times 10^{-6} m^2/s$. Find the thermal boundary layer thickness (in mm) at 0.5 m from the leading edge of the plate. (Use Blassius Results of Fluid Flow)

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QUESTION:49

Air flows over a surface of 2 m in length oriented in the direction of flow with sufficient breadth maintained at 150^0C, the pressure is 100 m and the bulk temperature is 30^0C. If the air velocity is 12 m/s, Find the average heat transfer coefficient if the properties of the fluid at the film temperature $T_f = \frac{150+30}{2} = 90^0$C

$\rho = 0.962$ kg/m^3, K=0.031 W/m-K, μ=2.131×10^{-5} Pa-s

c_p=1 kJ/kg-K

Use relations:

$$Nu = 0.332 Re_x^{1/2} Pr^{1/3} \quad \text{(Laminar)}$$

$$Nu = 0.0296 Re_x^{4/5} Pr^{1/3} \quad \text{(Turbulent)}$$

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QUESTION:50

The ratio of Laminar hydrodynamic layer to thermal boundary layer thickness of the flows of two fluids P and Q on a flat plate are 1/2 and 2 respectively. The Reynolds number based on the plate length for both the flows is 10^4. The Prandtl and Nusselt numbers for P are 1/8 and 35 respectively. Find the Prandtl and Nusselt numbers for Q.

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QUESTION:51

Air flows over the heated flat plate at a velocity of 50 m/s. The local skin friction coefficient at a point on the plate is 0.004. Estimate the local heat transfer coefficient at this point. The following properties data for air are given as:

$$\rho = 0.88 \text{ kg/m}^3$$
$$\mu = 2.286\ 10^{-5} \text{ kg/m-s}$$
$$c_p = 1.001 \text{ kJ/kg-K}$$
$$K = 0.035 \text{ W/m-K}$$

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FORCED CONVECTION (INTERNAL FLOW)

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QUESTION:52

For flow through a pipe of radius R, the velocity and temperature distribution are as follows:

$$u(r,x) = C_1 \quad \text{and} \quad T(r,x) = C_2\left[1 - \left(\frac{r}{R}\right)^3\right]$$

Where C_1 and C_2 are constants. Find out the Bulk Mean Temperature of the flow.

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QUESTION:53

The wall of a constant diameter pipe of length 1 m is heated uniformly with flux q'' by wrapping a heater coil around it. The flow at the inlet to pipe is hydrodynamically fully developed. The flow is incompressible and assumed to be laminar and steady all through the pipe. The bulk temperature of the fluid is equal to the 0^0C at the inlet and 50^0C at the exit. The wall temperatures are measured at the three locations P, Q, R as shown in the figure. The flow thermally develops after some distance from the inlet. The following measurements are made.

Among all the locations P, Q, R shown find the location from where flow becomes fully developed.

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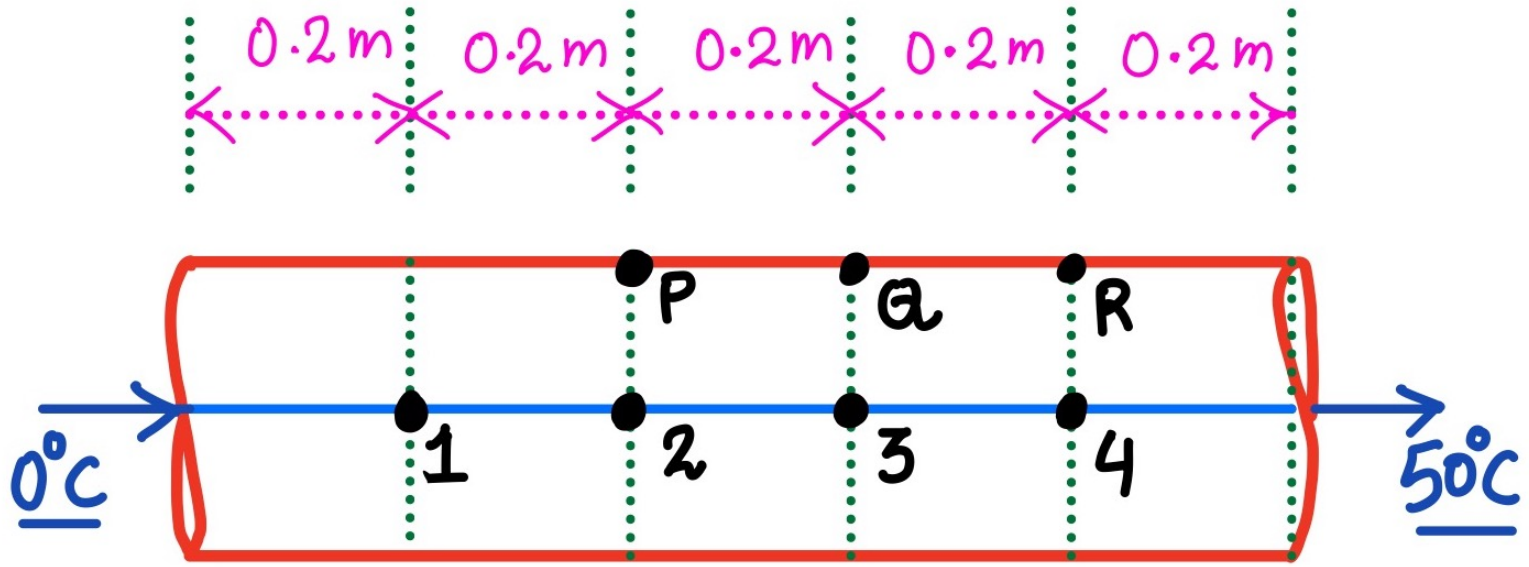
POINT	P	Q	R
WALL TEMPERATURE (in ^0C)	50	80	90



QUESTION:54

Water (c_p=4.18 kJ/kg-K) enters a pipe at a rate of 0.01 kg/s and temperature of 20^0C. The pipe of diameter of 50 mm and length 3 m, is subjected to wall heat flux q''_W in W/m^2. Find:

(a) If q''_W =2500 x, Where x is in meters and in the direction of flow ($x = 0$ at the inlet), find the bulk mean temperature of the water leaving the pipe.

(b) If $q''_W = 5000$, and the convective heat transfer coefficient is 1000 W/m^2-K, find the temperature in ^{0}C at the inner surface of the pipe at the outlet.

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QUESTION:55

An un-insulated air conditioning duct of rectangular cross-section 1m×0.5m, carrying air at 20^0C with a velocity of 10 m/s, is exposed to an ambient of 30^0C. Neglect the effect of duct construction material. For the air in the range of 20^0C-30^0C, data are as follows: K=0.025 W/m-K, μ=18 μPa-s, Pr=0.73, ρ=1.2 kg/m^3.Use Nusselt number:

For constant wall temperature conditions

$$Nu = 3.4 \quad \text{(Laminar)}$$

$$Nu = 0.023 Re_x^{0.8} Pr^{0.33} \quad \text{(Turbulent)}$$

(a) Find the Reynolds number for the flow.

(b) Find the heat transfer per meter length of the duct.

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QUESTION:56

Water flows through a tube of a diameter of 25 mm at an average velocity of 1 m/s. The properties of water are ρ=1000 kg/m^3, μ=7.25 × 10^4 Pa-s, Thermal conductivity K=0.625 W/m-K, Pr=4.85,

Using:

$$Nu = 0.023 Re_x^{0.8} Pr^{0.4}$$

Find the convective heat transfer coefficient in W/m^2-K.

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QUESTION:57

For turbulent flow in a tube, the heat transfer coefficient is obtained from the *Dittus-Boelter* equation. If the tube diameter is halved and the flow rate is doubled, the find the fraction by which heat transfer coefficient be changed.

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QUESTION:58

Find the average film coefficient heat transfer on the water side of a single pass steam condenser(100^0C Steam). The inner diameter of the tube is 23 mm and the cooling water enters at 15 ^{0}C and leaves at 25^0C. The average water velocity is 2.1 m/s. Sketch the system and the temperature distribution. Properties of the water is given below. Also find the heat transfer per meter length of tube in this case.

Temp (^{0}C)	Density (kg/m^3)	Sp. Heat (kJ/kg-K)	Sp. Thermal Conductivity x 10^2 (W/m-K)	Viscosity x 10^2 (kg/m)	Pr	Kinematic Viscosity ν x 10^6
10	1000	4.192	57.498	469	9.52	1.306
20	1000	4.183	59.780	361.892	7.02	1.006
30	1000	4.174	61.345	288.650	5.42	0.805

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NATURAL (FREE) CONVECTION

BY

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QUESTION:59

A 320 cm high vertical pipe at 150^0C wall temperature is in room with still air at 10^0C. This pipe supplies heat at a rate of 8 kW into the room air by natural convection. Assuming laminar flow, find the height of the pipe needed to supply 1 kw heat.

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QUESTION:60

A 30 cm long glass plate is hung vertically in the air at 27^0C while its temperature is maintained at 77^0C. Calculate the boundary layer thickness at the trailing edge of the plate. Use the following relation in free convection.

$$\delta_L = x[3.93Pr^{1/2}(0.952 + Pr)^{1/4}Gr^{-1/4}]$$

If the similar plate is placed in wind tunnel and air is blown over it at a velocity of 4 m/s, estimate the boundary layer thickness at the trailing edge. Properties of air at film temperature are:

K=0.02815 W/m-K, ν=18.41×10^{-6} m^2/s, Pr=0.7, β=3.07×10^{-3} K^{-1}

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QUESTION:61

Calculate the convective heat loss from the radiator 0.5 m wide and 1 m high maintained at the temperature of 84^0C in a room of 20^0C.

Treat the radiator as the vertical plate. The properties of air at the film temperature are:

K=0.02815 W/m-K, ν=18.41×10^{-6} m^2/s, Pr=0.7

Use the following relation in turbulent flow:

$$\overline{Nu_L} = \left\{ 0.825 + \frac{0.387 Ra_L^{1/6}}{\left[1 + \left(\frac{0.492}{Pr}\right)^{9/16}\right]^{8/27}} \right\}^2$$

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QUESTION:62

A thin 80 cm long and 8 cm wide horizontal plate is maintained at a temperature of 130^0C in a large tank full of water at 70^0C. Estimate the rate of heat input into the plate necessary to maintained the temperature of 130^0C. The properties of water at film temperature are:

K=0.68 W/m-K, ν=0.294×10^{-6} m^2/s, β=0.75×10^{-3} K^{-1}, c_p=4216 J/kg-K, ρ=960.63 kg/m^3, α=1.68×10^{-7} m^2/s

Use the following relations:

$$\overline{Nu_L} = 0.15(Ra_L)^{1/3}$$ **(At Top Surface)**

$$\overline{Nu_L} = 0.27(Ra_L)^{1/4}$$ **(At Bottom Surface)**

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